MODEL CODE FOR THE CONTROL OF RESIDENTIAL HAC DISTRIBUTION SYSTEM LEAKAGE AND HAC-INDUCED BUILDING LEAKAGE

PHILIP WEMHOFF
President
Philip Wemhoff and Associates
Jacksonville, Florida

Abstract and Introduction

Modifications to local and state codes are seen as an appropriate strategy for the prevention of residential air distribution system leakage and its impacts. A model code element has been developed to assist this strategy.

Recent field studies of Florida residences by Cummings, Tooley and Moyer[1] have revealed a mean leakage of 11 percent for the air distribution systems of central, fan-forced heating and air conditioning systems. Such leakage may cause an estimated 20 percent increase in energy consumption for air conditioning, as well as a 50 percent increase in peak cooling load and an 80 percent increase in peak heating load. In addition, building air leakage may be expected to be several times greater when duct leakage is present or when avenues of air egress from closeable rooms are absent.

The model duct construction element presented here contains all of the standards, definitions and code language needed to replace the current duct construction element of the local or state code. The content of this paper was used as a principal source for language adopted for the 1991 Florida Energy Efficiency Code For Building Construction.

Addressed are the most appropriate standards required for the closure and sealing of metal duct, rigid fibrous glass duct, and nonmetallic flexible duct. Also addressed are (1) detailed requirements for the sealing of mechanical closets when they function as plenum chambers, (2) detailed requirements for the sealing of enclosed support platforms for air handlers and furnaces when they function as return duct, (3) detailed requirements for the sealing of uninhabitable cavities of the building structure, when they function as duct, and (4) detailed requirements for the egress of air from enclosed rooms which receive supply air. Where necessary, commentary is provided to explain the options available for implementing the model code provision as well as its ramifications.

All provisions of this model code are compatible with the requirements, standards and guidelines contained in related documents published by the following organizations: the Southern Building Code Congress International, Inc., the Sheet Metal and Air Conditioning Contractors National Association, the American Society of Heating, Refrigerating and Air Conditioning Engineers, Underwriters Laboratories, Inc., the Air Conditioning Contractors Of America, the Thermal Insulation Manufacturers Association, the National Fire Protection Association, and the Gypsum Association.

[1] Cummings, J.B., Tooley, J.J., Jr., and Moyer, N., "Duct Leakage Impacts on Airtightness, Infiltration, and Peak Electrical Demand in Florida Homes," Florida Solar Energy Center and Natural Florida Retrofit, Inc., 1990.

Table Of Contents

100.0 HVAC Air Distribution Systems
- **(a) Air Distribution System Component Construction**
  1. **Metal duct systems, rigid and flexible.**
  2. **Nonmetallic duct systems, flexible.**
  3. **Fibrous glass duct systems, rigid.**
  4. **Installation and application procedures for the use of pressure-sensitive, aluminum foil-backed tapes.**
  5. **Combination duct systems.**
  6. **Terminal and intermediate fittings.**
  7. **Air handling units.**
  8. **Cavities of the building structure.**
- **(b) Mechanical Closets And Enclosed Support Platforms**
  1. **Mechanical closets meeting the definition of plenum chamber.**
  2. **Enclosed support platforms containing return duct.**
  3. **Treatments of through-wall, through-floor, and through-ceiling returns.**
- **(c) Air Duct System Insulation**
- **(d) Return Air Requirements**

Appendix: Definitions
Appendix: Standards

100.0 HVAC Air Distribution Systems

In the matter of duct sealing and insulation, the provisions of this code shall supersede all other codes and standards. The purposes of the provisions of this section are to preclude the unintentional leakage of air into or out of the air distribution system and to control thermal gains and losses resulting from conduction.

(a) Air Distribution System Component Construction

When the components of the air distribution systems, as defined by the subsections of this section, are constructed and sealed according to the requirements of this section, including the standards as referenced by and as limited by this section,[2] they shall be deemed to be substantially airtight and shall be deemed as meeting the intent of this code.

[2] This paragraph is stating that certain external standards are adopted as part of this code, but that in some cases they may be "limited" by the code, meaning that not all elements of the external standard have been adopted.

Proceedings of the Seventh Symposium on Improving Building Systems in Hot and Humid Climates, Fort Worth, TX, October 9-10, 1990

1. **Metal duct systems, rigid and flexible.**
   a. All ducts and duct fittings (see Definitions) located outside of the conditioned boundary of a building shall be sealed to meet the equivalent of Seal Class A requirements of Standard SMAC-1, which provides that all transverse joints, longitudinal seams and duct wall penetrations shall be sealed. However, round or oval metal ducts, operating below one (1) inch water gauge and utilizing a snap-lock longitudinal seam shall be exempt from the required seal of the longitudinal seam.[3]
   b. Duct systems designed to operate at pressures greater than three (3) inches water gauge (4 inches water gauge pressure class) shall be sealed to Seal Class A requirements of Standard SMAC-1, and tested in accordance with Standard SMAC-3. The tested duct leakage class, at a test pressure equal to the design duct pressure class rating, shall be equal to or less than Leakage Class 6. Leakage testing may be limited to representative sections of the duct system but in no case shall such tested sections include less than 25 percent of the total installed duct area and 25 percent of the transverse joints for the designated pressure class.
   c. Duct systems designed to operate at three (3) inches water gauge pressure class, that is, two (2) inches water gauge pressure through three (3) inches water gauge pressure, and located within the conditioned boundary of a building shall be sealed as a minimum to Seal Class B requirements, that is transverse joints and longitudinal seams shall be sealed.
   d. Duct systems designed to operate at two (2) inches water gauge pressure class or less and located within the conditioned boundary of a building shall be sealed as a minimum to Seal Class C requirements, that is transverse joints shall be sealed. Longitudinal seams need not be sealed.
   e. Closure systems.
      1). Rigid metal duct and duct fittings experiencing operating pressures of one (1) inch water gauge or greater and all flexible metal duct regardless of operating pressures: All transverse joints, longitudinal seams and joints between duct sections and other distribution system components such as duct fittings shall be welded or shall be mechanically fastened and sealed using either mastic or mastic-plus-embedded-fabric.
      2). Rigid metal duct, experiencing operating pressure less than 1 inch water gauge:
         a). Transverse joints and joints which could experience flexure. Closure options shall be limited either to mastic, mastic-plus-embedded-fabric, or to pressure-sensitive tape utilizing an acrylic-based adhesive.[4]
         b). Longitudinal seams. Closure options shall be limited to mastic-plus-embedded fabric and to pressure-sensitive tape utilizing an acrylic-based adhesive. However, round or oval metal ducts utilizing a snap-lock longitudinal seam shall be exempt from the required seal of the longitudinal seam.
      3). Conditions on the use of closure systems.
         a). Mastic-plus-embedded-fabric. Such closure systems shall be installed according to the installation and application procedures of TIMA-1. Following the adoption of standard UL181A for mastic-plus-embedded-fabric systems, such closure systems shall meet this standard.
         b). Pressure-sensitive tapes. Where indicated in Section 100.0(a)1.e., pressure-sensitive tapes may be used, provided that they utilize an acrylic-based adhesive and that the installation and application procedures of Section 100.0(a)4. and of TIMA-1 are observed. Pressure-sensitive tapes utilizing rubber-based adhesives shall not be used.
   f. Mechanical fastening to mechanical equipment. When a section of metal duct is joined to mechanical equipment, there shall be established sufficient mechanical fastening between the duct and mechanical equipment to support the duct independently of the closure system.

2. **Nonmetallic flexible duct systems.**
   Nonmetallic flexible duct, comprised of a wire-reinforced inner lining, an insulation layer and an outer jacket, shall be sealed and fastened to all other duct system components using a duct fitting (see Definitions). All sealing materials enumerated below shall meet Class 1 Surface Burning standards (see Definitions).
   a. Sealing and fastening the wire-reinforced inner lining to the duct fitting. The reinforced inner lining shall be sealed to the duct fitting using one of the following four sealing materials: (1) gasketing, (2) a mastic, (3) a mastic-plus-embedded fabric, or (4) a pressure-sensitive tape certified to meet Part I of UL-2 [UL181A], as indicated by a marking of "UL 181A-P" on the tape, or a pressure-sensitive tape having equivalent performance which is certified for this application under another part of UL-2 [UL181A], when such part shall become effective. In no case shall tapes utilizing rubber-based adhesives be used. When an approved tape is used, the following procedures shall be observed: (a)

[3] A joint study group of ASHRAE, SMACNA and TIMA, reported by ASHRAE 1989 Fundamentals Handbook, Chapter 32, found very low leakage for the unsealed longitudinal seams of round snap-lock metal duct, when such duct was operated at pressures of one (1) inch water gauge and below.

[4] This specification is consistent with ASHRAE Standard 90A, p. 23-24, which provides that "all transverse joints shall be sealed using mastic or mastic plus tape."

all unnecessary substances which may diminish the bond, including dust, dirt, oil, grease and moisture, shall be removed entirely from all receiving surfaces; (b) the tape, which shall be free of punctures, shall be applied such that it extends a minimum of 2 inches onto the duct lining and 1.5 inches onto the duct fitting, with all tape overlaps exceeding 1 inch; (c) in no instance shall the tape be made to form a right angle in either its long or short dimension, and (d) the tape shall be burnished to the extent that the underlying patterns of the duct lining and fitting produce impressions within the tape.

b. Mechanical attachment of the duct to the duct fitting (see Definitions).
   1). Attachment of the inner lining. In all cases a draw tie shall be installed directly over the wire-reinforced inner lining for the purpose of fastening it to the duct fitting. When the flexible duct is larger than 12 inches in diameter, the drawband shall be secured by a raised bead or indented groove on the fitting.
   2). Attachment of the outer jacket. Using a separate draw tie, the outer jacket shall be fastened to the duct fitting, and this separate draw tie shall be installed over the composite of the outer jacket and the insulation layer. The outer jacket shall not be attached to the duct product (fibrous glass duct board or sheet metal duct) at the other end of the fitting.
   3). Inspection. The attachment of the outer jacket to the fitting shall be delayed until after a duct inspection, so that the seals and attachments between the inner lining and duct fitting and between the duct fitting and the rigid duct board or sheet metal may be examined.

c. Sealing the duct fitting (see Definitions) to all air ducts. The seal between a duct fitting and a section of nonmetallic flexible duct shall be accomplished according to the requirements of 100.0(a)2.a. and b., above. The seal between a duct fitting and rigid fibrous glass duct board or sheet metal requires the use of an integral-flange duct fitting (see Definitions; no other type of fitting may be used) having a flange of 5/8 inch minimum width which is sealed to the duct board or sheet metal by one of the following methods.
   1). The placing of a mastic or gasketing between the flange of the duct fitting and the rigid duct board or the sheet metal;
   2). the application of a mastic-plus-embedded fabric to the joint between the flange and the rigid duct board or the sheet metal;
   3). the application of tape, meeting UL-2 [UL181A], to the joint between the flange and the rigid duct board or the sheet metal in such a manner that the tape will adhere well to all surfaces, will cover the flange and will extend a minimum of one inch onto the duct board.

   In no instance shall any part of a nonmetallic flexible duct section be interposed between the flange of the duct fitting and the rigid duct board or sheet metal.[5]

d. Nonmetallic Flexible Duct Installation and Support. Nonmetallic flexible ducts shall be configured and supported so as to prevent the use of excessive duct lengths, to prevent duct and joint dislocation or damage, and to prevent constriction of the duct below the rated duct diameter. The following requirements shall apply to all nonmetal flexible air ducts and air connectors.
   1). Such duct shall be supported at the manufacturer's recommended intervals, but in no case shall the distance between supports exceed 10 feet. Duct sag between supports shall not exceed 1/2 inch per foot of spacing between supports.
   2). The length of duct material used for a given run, if extended, shall not exceed by more than five (5) percent the minimum extended length needed for that run. Ducts shall be installed fully extended.
   3). Ducts shall be supported within 1.5 feet of an intermediate fitting when the intermediate fitting is attached at its flange-end to fibrous glass duct board. All supports shall be distinct from the duct system and shall maintain contact with the lower one-half of the circumference of the outer jacket. When a bend is to occur near an intermediate fitting, the duct shall be extended straight outward from the fitting for several inches before beginning the bend, and the duct shall be supported between the fitting and the bend. Terminal fittings shall be supported independently of the flexible duct.
   4). The inside diameter of a bend shall exceed the outside diameter of the specific duct product undergoing the bend. Long horizontal duct runs with sharp bends shall have supports before and after the bend, located within one (1) duct

5 This statement prohibits the use of "diapered" joints, a joint prone to faulty assembly and leakage. Such joints (and all other compression joints) are not now, nor have they ever been, recognized as acceptable closure methods by industry consensus fabrication standards as expressed in SMAC-2, SMACNA HVAC Duct Systems Inspection Guide (1989), and in SMAC-1, SMACNA HVAC Duct Construction Standards: Metal and Flexible (1985), and in their predecessors: SMACNA Flexible Duct Performance Standards and Flexible Duct Installation Standards (1980) and SMACNA Flexible Duct Installation Standards (1979). In addition, no duct manufacturer is prohibited from using his product by the barring of these joints. According to Jack Bono, then-President of Underwriters Laboratories, Inc. in a written communication to the Jacksonville Electric Authority, dated February 8, 1990, "It is my understanding that all UL-Listed ducts which have provisions for use of the diapered joints, are also Listed with provisions for other joint connection methods. Therefore, the use of diapered joints does not appear mandatory for any of the currently-Listed products."

diameter distance from the beginning and end of the bend.

5). Where used, supports in contact with the flexible duct shall be of sufficient width to prevent any restriction of the internal diameter of the duct when the weight of the supported section rests on the support. In no case shall the material contacting the flexible duct be less than one (1) inch wide.

6). Vertically-installed duct shall be stabilized by support straps at a maximum of six (6) feet on center.

3. **Fibrous glass ducts systems.**
All rigid fibrous glass ducts and plenums shall be constructed according to the provisions of Standard TIMA-1 as modified by the conditions below.

a. Where they must be sealed. All transverse joints, longitudinal seams and duct wall penetrations shall be sealed. All joints and seams are affected, including, but not limited to, the joints between sections of duct and the joints between duct and other distribution system components, such as terminal and intermediate fittings and the supply and return ends of air handler and furnace cabinets. When a section of duct, fabricated of fibrous glass duct board, is joined to mechanical equipment, there shall be established sufficient mechanical fastening between the duct and mechanical equipment to support the duct independently of the closure system.

b. Closure system requirements. All closure products shall meet Class 1 Surface Burning standards, at minimum, and shall be applied in accord with standard TIMA-1 to the air barrier (see Definitions) of the mated duct materials in order to form a continuous barrier to the leakage of conditioned air. One of the following groups of closure products shall be used:

1) Closure products which are in accord with the manufacturer's Listing for the duct product to which it is to be applied; or

2) Closure products which meet the provisions of UL-2 [UL 181A], to include complying pressure-sensitive and heat-activated tapes when such provisions shall become effective. Pressure-sensitive tapes and heat-activated tapes may be used only if they are installed strictly according to the provisions of TIMA-1 and of 100.0(a)4., below; or

3) Mastic and mastic-plus-embedded-fabric products which meet the provisions of UL-1 [UL181] or the appropriate part of UL-2 [UL181A] when such provisions shall become effective.

4. **Installation and application procedures for the use of pressure-sensitive, aluminum foil-backed tapes on metal duct and fibrous glass duct board.**
All pressure-sensitive tapes shall be applied and installed according to the requirements of TIMA-1, Section III, including but not limited to the following requirements:

a. Surface preparation. The surfaces upon which closure products are to be applied shall be clean and dry. Dust, dirt, oil, grease, moisture and other unnecessary substances which may diminish the bond shall be removed entirely, by solvents if necessary, from the receiving surface.

b. Cold weather conditions. At temperature below 50 °F, pressure-sensitive tapes shall not be used, unless the following conditions have been achieved: (1) that the tape will have been maintained at a temperature of 70 °F during use and for 12 hours prior to use, (2) that immediately prior to applying the tape the receiving surface has been pre-heated by the application of a 400 ± 25 °F iron, and (3) that, immediately following its application, the tape has been heated in place by the application of a 400 ± 25 °F iron.

c. Tape application. The tape shall be centered over the joint or seam, and it shall be burnished to the extent that the underlying patterns of the seam (and for fibrous glass duct board the patterns of the scrim reinforcement and staples) produce impressions within the tape. After its application it shall be free of wrinkles; it shall be uniformly adhered, and it shall be free of punctures.

5. **Combination duct systems.**
Duct systems combining metal, fibrous glass or nonmetallic flexible ducts shall meet the sealing requirements provided in subsections 100.0(a) 1., 2., or 3., respective to each duct type used.

6. **Terminal and intermediate fittings.**
Fitting subsections. All seams and joints within duct fittings (see Definitions) and between fitting subsections through which air leakage could occur, if unsealed, shall be sealed. If the seam or joint is metal-to-metal or metal to the foil cladding of duct board, the closure systems approved for metal ducts, Section 100.0(a)1., shall be used. If the seam or joint occurs between sections of fibrous glass duct board, the closure systems approved for fibrous glass ducts, Section 100.0(a)3., shall be used.
Fitting to duct joints. Joints between metal duct and duct fittings, including mechanical equipment, shall be sealed according to the provisions of Section 100.0(a)1., and joints between fibrous glass duct and duct fittings, including mechanical equipment, shall be sealed according to the provisions of Section 100.0(a)2.b. When a tab-fastened fitting is joined to duct board, all functional tabs shall be employed in securing the fitting, **{Optional:** and the fitting shall incorporate a ring of one (1) inch minimum width between the tabs of the fitting and the duct board[6].

6 The use of a tab-ring is a current requirement in many local jurisdictions. The ring strengthens the attachment against torque

The ring shall be sufficiently rigid to distribute uniformly the forces applied by the tabs.}

7. **Air handling units.**
All air handling units located outside the conditioned space shall be sealed to the equivalent of Seal Class A of Standard SMAC-1, which provides that all joints, seams and penetrations be sealed.

8. **Cavities of the building structure.**
   a. When uninhabitable cavities of the building structure are used to transport air between a heating or air conditioning unit (HAC unit) and air distribution system return inlet(s) or supply outlet(s), those cavities shall be so sealed as to preclude the possibility of any air leakage between them and any non-conditioned space or between them and any building cavity not intended for this air transport. Such uninhabitable cavities shall include but shall not be limited to soffits, wall cavities and through-wall transfer grilles, whether or not such cavities are attached directly to return or supply duct or to the HAC unit.
   b. Sealants used to close such cavities shall be limited to either mastics or mastics-plus-embedded-fabrics and shall meet standard SMAC-1, Section 1.9, which requires prudent selection and application of sealing materials. If material specifications for the necessary air containment materials and sealants are absent from the local mechanical code, the air containment materials and sealants utilized shall meet Class 1 Surface Burning standards.
   c. All ducts, including all duct located in duct chases, when they penetrate the building envelope, shall be sealed directly to that component of the building envelope (ceiling, floor or wall) which is penetrated using, where necessary, acceptable materials to bridge the spaces between the duct and the building envelope component.[7]

(b) Mechanical Closets And Enclosed Support Platforms For Central Air Conditioning And Heating Systems

Mechanical closets. A mechanical closet for a central heating or air conditioning unit (HAC unit) is considered a plenum chamber, if return air, when it enters the mechanical closet, is confined by the walls, ceiling and floor of the mechanical closet during its journey to the HAC unit, so that the outer walls of the air handler or furnace are exposed to the return air stream. Such plenum chambers, whether they are located inside or outside the conditioned space, shall meet the requirements of section 100.0(b)1., below. When a combustion appliance, including a combustion furnace or water heater, is located within a mechanical closet, the mechanical closet shall not be utilized as a plenum chamber.

Enclosed support platforms. When an enclosed platform supports a central heating unit or the air handler of a central air conditioner or heat pump and provides a housing for the transport of return air from the return air inlet(s) to the inlet of the heating or air conditioning unit, the platform shall contain a duct section fabricated to contain without leakage the return air stream. Such support platforms and return duct sections, whether they are located inside or outside the conditioned space, shall meet the requirements of section 100.0(b)2., below.

1. **Mechanical closets meeting the definition of plenum chamber.**
When a mechanical closet meets the definition in 100.0(b) of a plenum chamber, regardless of its location, it shall be sealed in such a way as to preclude any air leakage into the return air stream from the cavities of adjoining walls[8] or from outside the conditioned space. Sealing shall be accomplished by implementing Part a., below, using materials as required by Part b.
   a. Part a. Establishing a continuous air barrier (see Definitions) on the inside surface of a mechanical closet functioning as a plenum chamber.
      1). Air barrier location. The interior walls, ceiling and floor of the mechanical closet shall be sheathed continuously with a panelized material, which may be gypsum wallboard, capable of performing the function of an air barrier, and it shall meet the material requirements described below in 100.0(b)1.b. The floor of the mechanical closet may be excluded from this requirement if its construction within the sealed portion of the mechanical closet is continuous, fissure-less concrete[9].
      2). Seals and sealants. (a) A sealant meeting the material requirements below shall be used to seal all joints between wall sheathing panels and the bottom plate, between the bottom plate and the floor, between wall and ceiling

and prolongs the seal by minimizing the crushing of the duct board and the potential loosening of the fitting; erosion is also reduced.

7 When an air handler is on the first story of a two-story dwelling, a chase is often used to route duct to the attic for air delivery to the second floor. As a result of this chase, the attic and the space between the first and second floor and the mechanical closed on the first floor are often in hydraulic communication. And, if a direct, free-air return is used, the attic air may be drawn into the return air stream.

8 This code language eliminates the need to establish the origin of leakage air as air from outside the conditioned space. It is often perceived, incorrectly, that attic air cannot be drawn through partition walls into the mechanical closet from an attic immediately above the mechanical closet. In addition, it is often argued, in error, that air leakage from wall cavities into a mechanical closet located on the first floor of a two-story building could not have its origin outside the conditioned space. In fact this could well be the case, with air entering second-floor partition walls from the attic, passing through the between-floor space and into first-floor partition walls.

9 A wood panel floor would not meet the Class 1 Surface Burning standards required by the Standard Mechanical Code (Section 509) of all exposed surfaces within a plenum chamber.

panels, between wall panels and the door jambs, and between wall panels and the air handler support platform, if one is present; (b) adjoining wall sheathing panels shall be sealed to each other using a sealant meeting the material requirements of this section. Gypsum wallboard joint compound shall not be an acceptable sealant.[10] If the sheathing material is gypsum wallboard, sealants may be omitted at flat, vertical butt joints, only, provided that the gypsum wallboard panels are attached using adhesives meeting standard ASTM C 557, and are installed in accordance with Section 6 of Standard GYPS-1, which recommends that a separate bead of adhesive be located between each panel and the common vertical framing member.

3). Penetrations. All air ducts, service lines, refrigerant lines, electrical wiring, condensate drain lines, mechanical equipment support platforms[11], and all other objects, excluding sheathing fasteners, which penetrate the sheathing of the ceiling, walls or floor of the mechanical closet, shall be sealed to this sheathing, or floor if it is penetrated, on the inside surface using a sealant meeting the material requirements below in 100.0(b)1.b. The refrigerant line chase, if it emerges within the mechanical closet, shall be sealed to close both its inside and outside openings.

b. Part b. Material requirements.

1). Sheathing material. The sheathing material shall comply with the following standards: (a) it shall have an air porosity (see Definitions) no greater than that of a duct product meeting standard UL-1 [UL181], Section 22, or that of undamaged, intact one-half inch thick gypsum wallboard[12] as defined by ASTM C 36, and (b) it shall meet Class 1 Surface Burning standards. In addition, the provisions of local mechanical codes related to plenum chambers shall further define acceptable sheathing materials.[13] If fibrous glass duct board is used, its foil air barrier shall face the inside of the mechanical closet.

2). Sealants. Sealants, which shall be mastics, mastics-plus-embedded-fabrics or one-part tape systems, shall meet (a) Class 1 Surface Burning standards, (b) standard SMAC-1, Section 1.9[14], which requires the prudent selection and application of sealing materials, and (c) applicable provisions of the locally-adopted mechanical code.[15] If the sealant is used to close rigid fibrous glass duct board, it shall be applied according to standard TIMA-1. Gypsum wallboard joint compound shall not be considered an acceptable sealant[16].

2. Enclosed support platforms containing return duct.

a. Mandatory duct section. When an enclosed support platform is located between the return air inlet(s) from conditioned space and the inlet of the air handling unit or furnace, it shall contain a duct section constructed entirely of rigid fibrous glass duct board or rigid sheet metal and be insulated according to the requirements of section 100.0(c). This duct section shall be so designed and so constructed that (1) no portion of the support platform or of the building structure, including adjoining walls, floors and ceilings, shall be in contact with the return air stream or function as a component of this duct section and (2) the duct section shall be effectively isolated from the building structure, so that air

10 Sealants to meet this Class 1 Surface Burning requirement are not difficult to acquire and are not expensive. Most acoustical sealants, formulated to adhere well to gypsum wallboard, are available at gypsum product suppliers and cost approximately $4.00 per one-quart tube. Some brands which meet the Class 1 Surface Burning standard for flame spread and smoke development are Ohio Sealant Rubber Base Sound Sealant and Ohio Sealant Water Base Sound Sealant (800 321-3578), Tremco Acoustical (Rubber Base) Sealant (800 321-7906), and US Gypsum Acoustical (Water Base) Sealant (800 342-0585).

11 If there is a support platform which is attached by ledgers to the wall framing (which is frequently the case), the top of the support platform (as well as the ledgers) will penetrate the wall sheathing. A new development has been the direct attachment of air handlers to a wall using a bracket made of sheet metal. This bracket does not usually penetrate the sheathing.

12 The definition of non-combustible in the Standard Building Code is intended to apply to gypsum wallboard. This code, pages 14 and 15 accepts as non-combustible "Materials having a structural base (meaning the gypsum) of noncombustible materials as defined in 1 (by ASTM E 136), with a surfacing (meaning the paper facing) not more than 1/8 inch thick which has a flame spread rating not greater than 50 (no requirement related to smoke developed rating) when tested in accordance with ASTM E 84."

13 For example, the Standard Mechanical Code, Section 509, provides that this sheathing material and the floor covering must be either non-combustible materials or must meet Class 1 Surface Burning standards (see Definitions). Most gypsum wallboards and all UL181-rated fibrous glass duct boards meet the Class 1 Surface Burning standards, but most foam board insulations and wood panels do not.

14 Section 1.9 of SMAC-1 defines acceptable seals and prudent selection and application of sealing methods.

15 For example, the Standard Mechanical Code, Section 509, requires that all materials meet Class 1 Surface Burning standards.

16 Joint compound should not be used at any location in the plenum chamber to achieve a seal, for the following reasons: (a) it does not adhere to wood; so, it would not form a seal between the gypsum wallboard and the door jamb and between the wallboard and bottom plate or floor; (b) it should not be used on horizontal joints (between wall and ceiling), since truss uplift over time may break the joint compound which is thin and brittle; (c) it should not be used in corners because the panels on adjoining walls are attached to different framing members; if the walls are vibrated (which can happen, because air handlers are often hung from the walls), the joint compound may crack; however, (d) mastic can be omitted at vertical, butt joints, if adhesive is used to fasten the wallboard (see GYPS-1), because adjoining panels in these locations are mechanically fastened and glued to the same framing member; the adhesive (which by code should be applied in two separate vertical beads at butt joints) will assure air-tightness, and the joint compound, located between the air stream and the adhesive, will assure that the adhesive does not have to meet Class 1 Surface Burning standards.

cannot be transferred to the return air stream from the cavities of adjoining walls, floors or ceilings.

b. Closure requirements. The subsections of this duct section and its jointing to the mechanical equipment and to all other connecting duct sections shall be attached and sealed according to the respective requirements of section 100.0(a), to the extent that this closure effort shall preclude over the entire surface area of the duct section, including those areas not exposed to view, any present or future possibility of air leakage into the return air stream.

c. Penetrations of the duct section. {**Choose one of the following two options, A or B. [Option A:** In no instance shall a refrigerant line chase, refrigerant line, wiring, pipe or any object other than a duct fitting penetrate this duct section.[17]] **[Option B:** All objects penetrating this duct section shall be sealed to its air barrier (see Definitions), and the refrigerant line chase, if it emerges within this duct section, shall be sealed to close both its inside and outside openings.]}

d. Non-suporting enclosures. Enclosures, which are located directly below mechanical closets and which house passageways for return air, but which may not physically support mechanical equipment, are also covered by the requirements of this subsection.

3. **Treatments of through-wall, through-floor, and through-ceiling returns used to convey air from a return air inlet to a Mechanical Closet functioning as a plenum chamber or to an Enclosed Support Platform containing return duct.**

When a through-wall, through-floor or through-ceiling return is used, wood framing or fibrous glass duct board shall be installed within the wall, floor or ceiling cavity so as to surround the opening continuously, thereby isolating the return air passageway from the remainder of the cavity. The segments of this framing or duct board shall be sealed to each other, and this framing or duct board air barrier shall be sealed both (a) to the air barrier of the sheathing or duct board inside the mechanical closet or enclosed support platform and (b) to the gypsum wallboard or other wall, ceiling or floor panelling on the air-inlet or grille side of the opening. The effect of such treatment shall be to prevent the possibility of air leakage into the return air stream from the remainder of the wall, ceiling or floor cavity. Sealants shall meet Class 1 Surface Burning standards.

17 In no other application of residential duct is supply or return duct allowed to be penetrated by wires, pipes, and chases in communication with the soil. However, this prohibition would cause a departure from the current practice of placing the refrigerant chase within the support platform. As a result, additional space may be consumed in the garage to allow the chase to emerge outside of the duct section or outside of the support platform.

(c) Air Distribution System Insulation

All duct insulation values shall be determined by using flat specimens to determine thermal resistance (R) using the relationship R = t/k, where t is the installed thickness in inches and k (Btu-in/hr sq. ft. °F) is determined for the insulation using ASTM C 518 or ASTM C 177 and conducting the test at 75 °F mean temperature.

Duct wrap for metal duct. Such wrap shall be tested at 75 percent of its nominal thickness and the installed thickness value shall also be assumed to be 75 percent of the nominal thickness.

Rigid fibrous glass duct board and duct liner. For such products the nominal value shall be used for thickness.

Insulation for nonmetallic flexible ducts. Such insulation shall be tested at a thickness equal to the installed duct wall thickness. The installed duct wall thickness shall be determined by circumferentially cutting the outer jacket and insulation from a sample, removing it from the inner lining, laying it onto a flat surface and measuring its width with a rule, to the nearest 1/16 inch. The installed R-Value of the air duct or air connector, calculated in accordance with this standard, shall be printed or labelled on the product at 10 feet intervals, maximum.[18]

All ducts systems, plenums, and enclosures installed in or on buildings shall be thermally insulated as follows:

1. **Insulation requirements and effective dates.**

Prior to *effective date*[19], all air distribution system components, including, but not limited to, ducts, duct fittings, supply plenums, enclosures in or on buildings, or portions thereof, shall be insulated to provide a minimum installed thermal resistance, excluding air film resistances, of R-4.2.

As of the *effective date*, the minimum installed thermal resistance for all air handling system components shall be R-6.0.[20]

The floors of enclosed support platforms, if they function as return duct and are located outside the conditioned space, shall be insulated to meet these requirements.

When the wood flooring of a building functions as the floor of a plenum chamber, and if plenum chamber floor is located above a non-conditioned space, the wood floor shall be insulated to meet these requirements.[21]

18 This insulation-measuring standard and the labelling recommendation were adopted by the Air Diffusion Council, the association of nonmetallic flexible duct manufacturers, at its December, 1989 meeting.

19 The code jurisdiction would enter the desired effective date. Although this section provides for a time phasing from R-4.2 to R-6.0, the higher insulation level may be implemented immediately.

20 Refer to ASHRAE Standard 90.2P for the recommended duct insulation levels for your climate region. Although ASHRAE Standard 90.2P has not yet been adopted, that portion of the document dealing with duct insulation has remained unchallenged.

21 Since the wood floor would be exposed in a plenum chamber, to the return air stream, it would not fulfill the Standard Mechanical Code requirement that all exposed surfaces meet Class 1 Surface Burning standards, at minimum. If the wood floor were to be

2. **Additional insulation requirements.**
Additional insulation with vapor barrier shall be provided where the minimum duct insulation requirements of subsection 1., above, are determined to be insufficient to prevent condensation. However, insulation may be omitted when it can be shown that the criteria in subsection 1, above, have been met and that condensation resulting from its absence will not be detrimental to the distribution system, mechanical system or building structure, and that the health and safety of the building occupants will not be adversely affected.

3. **Omission of duct insulation.**
Duct insulation (except where required to prevent condensation) is not required in any of the following cases:
   a. When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building.
   b. Exhaust air ducts.

4. **Crawlspace plenums.**
Crawlspaces, whether sealed or unsealed, shall not be used as supply or return plenums.

(d) Return Air Requirements

All rooms, enclosed by a door and to which conditioned air is supplied, shall be equipped with a means for air egress, so that conditioned air will be able to return to the air handler or furnace. The size of the return air grille or outlet area shall be determined according to the following[22]:

1. **Ducted returns.**
If conditioned air is to be removed from an enclosed room by means of a ducted return, the design and size of the return duct and return grille should be determined using the methods of ASHR-1 or ACCA-1, or another approved method. However, in the absence of such sizing being performed, the size of the return grille shall be determined in the following manner:
   a. Non-filtered return grille of a ducted return:
   Required Net Free Grille Area (in Square Inches) = Supply Air CFM multiplied by 0.36 SqIn/CFM (For each 100 CFM of Supply Air there shall be 36 Square Inches of Net Free Grille Area, ± 12 percent);
   b. Filtered return grille of a ducted return:
   Required Net Free Grille Area (in Square Inches) = Supply Air CFM multiplied by 0.50 SqIn/CFM (For each 100 CFM of Supply Air there shall be 50 Square Inches of Net Free Grille Area, ± 12 percent).

   Note that this is not a sizing calculation for return duct. The Return Duct size should be determined using the duct design procedures of ASHR-1 or ACCA-1, or another approved method.[23]

2. **Other, non-ducted methods of air egress.**
If conditioned air is to exit an enclosed room by means of a through-wall grille, a through-door grille, an under-cut door, or by another non-ducted means, the Net Free Grille Area or Outlet Area shall equal or exceed the area determined by the following:
Required Net Free Grille Area (in Square Inches) $\geq$ Supply Air CFM multiplied by 0.36 SqIn/CFM (For each 100 CFM of Supply Air there shall be 36 or more Square Inches of Net Free Grille or Outlet Area).

   If an under-cut door is to be used for air egress, the arithmetic product of the door width times the distance between the door and the finished floor at its most restrictive location shall equal or exceed the Required Net Free Outlet Area. If the floor is finished with carpet, the distance shall be measured from the bottom of the door to the top of the uncompressed carpet nap.

   If a through-wall, through-floor or through-ceiling grille is to be used, the wall penetration shall receive the treatments of section 100.0(a)8. and 100.0(b)3.

Appendix: Definitions

Air Barrier or Air Containment Material. When used in relation to air duct and plenum chambers, it is a material (1) which is used in direct contact with supply or return air as part of the air distribution system and (2) which has an air porosity no greater than that of a duct product meeting standard UL-1, Section 22, or of undamaged, intact one-half inch thick gypsum wallboard as defined by ASTM C 36. The air barrier or air containment material may be a uniform panel, such as gypsum wallboard meeting ASTM C 36, which as a whole meets this air porosity standard, or it may be a foil or other membrane, such as the foil cladding on fibrous glass duct board, which alone meets this air porosity standard, but which is attached as a composite to a panelized material.

Air Duct. A conduit or passageway for transporting air to or from heating, cooling, air conditioning, or ventilating equipment. Included in this definition are supply plenums as well as air ducts and air connectors as referenced by UL181 and NFPA 90A and NFPA 90B.

covered with fibrous glass duct board, it would then meet both the insulation requirement and the Class 1 Surface Burning requirement.

22 The Net Free Grille Areas are derived from ACCA Manual D (1984) p. 25, which recommends a 400 FPM face velocity at return grilles and from SMACNA SMAC-4, p. 8.2, which states "Return air grilles shall be sized to return 100 percent of the air being supplied to the conditioned space with air velocities not to exceed 450 FPM face velocity."

23 Note also that in order to comply with standard SMAC-4, ducted returns shall not be used for air egress from bathrooms, kitchens, utility spaces, spaces used for storage of fuel or flammable materials, or from a confined space in which a draft diverter or draft regulator is located or to which combustion air is supplied. In these cases, non-ducted means of air egress should be used.

Air Porosity. A measure of the ability of a material to transmit air through the plane of the material.

Class 1 Surface Burning Standards. A product meets Class 1 Surface Burning standards if it exhibits the following surface burning characteristics when tested under either UL 723 or ASTM E 84 test procedures: a Flame Spread Rating of not over 25 without evidence of continued progressive combustion and a Smoke Developed Rating of not over 50. Compliance by a product with this definition is not equivalent to compliance with UL Standard 181. However, since the UL 723 test procedure is one part of the UL 181 standard, all products meeting the UL 181 standard also satisfy this definition. It is not mandatory that a product be tested solely by UL but only that it be tested under either UL 723 or ASTM E 84 test procedures.

Diapered Joint. A diapered joint is one formed between a duct fitting and nonmetallic flexible duct in which the outer jacket of the nonmetallic flexible duct passes over the flange of the duct fitting, between the flange and the rigid duct board, through a hole cut into the rigid duct board and into the duct cavity where it is attached to the fitting.

Draw Tie. A clamp which surrounds the mated union of a duct fitting and either the inner lining or the outer jacket of a section of nonmetallic flexible duct. The clamp, when tightened, shall fastening either the inner lining or the outer jacket to the duct fitting. A raised bead should be present on the duct fitting to prevent movement of the draw tie and to prevent separation of the union. Tension ties, clinch bands, draw bands, and straps are considered draw ties.

Duct Fitting. A general expression for all couplings used to join sections of air duct to other distribution system components. Duct fittings are used to join separate sections of nonmetallic flexible duct or to join a section of nonmetallic flexible duct to another distribution system component. Duct fittings may be classified as either *terminal* fittings or *intermediate* fittings. *Terminal* fittings join nonmetallic flexible duct and other air duct to supply outlets and return inlets at the ends of the distribution system; this class of fittings includes register and return boots and register and return boxes. *Intermediate* fittings join nonmetallic flexible duct to other sections of nonmetallic flexible duct, to sections of other types of duct such as rigid fibrous glass duct board, and to mechanical equipment components such as air handlers and furnaces; this class of fittings includes collars, take-offs, tap-ins, sleeves, and the supply and return ends of air handler cabinets and furnaces. A raised bead or an indented groove should be present on the duct fitting to prevent movement of the draw tie and thus detachment of the nonmetallic flexible duct from the duct fitting.

Enclosed Support Platform. A framed enclosure which supports a central heating unit or the air handler of a central air conditioner or heat pump. When such an enclosed platform provides a housing for the transport of return air from the return air inlet(s) to the inlet of the heating or air conditioning unit, the platform must contain a duct section fabricated to contain without leakage the return air stream. In jurisdictions which have adopted the Standard Mechanical Code, materials used in constructing return duct, if located within two feet of the heating unit casing, must meet either Class 0 or Class 1 Surface Burning standards. At distances of two feet and greater, return duct materials may be less fire resistant, with Flame Spread Ratings $\leq$ 200. Refer to Section 503, Standard Mechanical Code, for additional information on allowable materials. To meet the requirements of the National Fire Protection Association Standard 90B, which is incorporated by reference into the Standard Mechanical Code, that portion of return ducts directly beneath heating units with bottom-return shall be fabricated of non-combustible material(s), as tested under ASTM E 136, if incandescent particles could fall from the unit.

Gasketing. When used in relation to air distribution systems, a compressible, resilient packing capable of filling all gaps and creating an air-tight seal between the duct components being joined. It is a material which is distinct from the components being joined. Gasketing shall meet Class 1 Surface Burning standards.

Infiltration. The uncontrolled air leakage through cracks and openings in any building element and around windows and doors of a building, caused by the pressure effects of wind, HVAC distribution system leaks or the effect of differences between the indoor and outdoor air densities.

Integral-Flange Duct Fitting. A type of intermediate duct fitting. To be an integral-flange duct fitting, the fitting must have a flange of 5/8 inch minimum width which is mechanically attached to and sealed to the cylinder or sleeve of the fitting. A function of this flange is to provide a surface which can be sealed to rigid duct board.

Mastic. When used in relation to air distribution systems, a thick, pliable paste capable of filling gaps between the mated parts of distribution system components and of adhering well to them. Mastics shall meet Class 1 Surface Burning standards.

Mechanical Closet. A room which contains the blower unit of a central heating or air conditioning unit, which is less than 60 square feet in floor area, and which is enclosed by either a solid or louvered door. A mechanical closet may or may not be a plenum chamber.

Nonmetallic Flexible Duct. A type of round flexible air duct comprised of a three-layer composite. The innermost layer, which contacts the air stream, is a wire-reinforced inner lining, most often made of plastic and reinforced by a helical wire. The middle layer is an insulation blanket. And, the outermost layer is a scrim-reinforced jacket often made of plastic.

Plenum Chamber. A mechanical closet for a central air conditioning or heating unit is considered a plenum chamber, if return air, when it enters the mechanical closet, is confined by the walls, ceiling and floor of the mechanical closet during its journey to the air handler, so that the outer walls of the air handler or furnace are exposed to the return air stream. When mechanical closets are plenum chambers, their walls, ceilings, floors and other contents are restricted by the Standard Mechanical Code either (a) to materials which are non-combustible tested under standard ASTM E 136 or (b) to combustible materials which meet Class 1 Surface Burning standards: Flame Spread $\leq$ 25, Smoke Developed $\leq$ 50. For residential buildings, wood louvered doors, wood frame mechanical equipment supports and approved plumbing and electrical wiring are exempted by this mechanical code from these non-combustible and Class 1 Surface Burning requirements. The Standard Mechanical Code in Chapter 2, Definitions, apparently includes gypsum wallboard in its definition of non-combustible materials.

Plenum, Supply. Forming part of the distribution system and attached directly to the outlet of the central heating or air conditioning unit (HAC unit), the supply plenum is a dispensing manifold to which two or more supply ducts are connected. It is considered duct; and all closure, in-

sulation and other requirements of duct shall apply to the supply plenum.

Seal or Sealing. When used in relation to air distribution systems and mechanical equipment, a seal or sealing shall mean the use of any of the following closure systems: adhesives, gaskets, tape systems or combinations thereof, or continuous welds, to close joints, seams, and other openings in the surfaces of ductwork and air barriers through which air leakage would otherwise occur. No joint or opening from which a closure product is absent shall be considered sealed unless considered otherwise in specific cases identified by this Code. Closeness of fit between mated parts, alone, shall not be considered a seal.

Appendix: Standards

ACCA-1 Manual D: Duct Design For Residential Winter And Summer Air Conditioning And Equipment Selection, Air Conditioning Contractors Of America, 1984.

ASHR-1 ASHRAE Handbook, Fundamentals Volume, 1989 Edition, American Society of Heating, Refrigerating and Air Conditioning Engineers.

ASHR-2 ASHRAE Standard 90-A-1980, Energy Conservation In New Building Design, including Addenda 90A-a-1987, Addenda To Energy Conservation In New Building Design, American Society of Heating, Refrigerating and Air Conditioning Engineers.

GYPS-1 Recommended Specifications for the Application and Finishing of Gypsum Board, Gypsum Association, 1603 Orrington Avenue, Evanston, Illinois 60201. (This standard, as GA-216, is a part of the Standard Building Code by reference.)

SMAC-1 HVAC Duct Construction Standards, Metal and Flexible, First Edition 1985, Sheet Metal and Air Conditioning Contractors National Association, Inc.

SMAC-2 HVAC Duct Systems Inspection Guide, Sheet Metal and Air Conditioning Contractors National Association, Inc., 1989.

SMAC-3 HVAC Air Duct Leakage Manual, First Edition, Sheet Metal and Air Conditioning Contractors National Association, Inc., 1985.

SMAC-4 Installation Standards for Residential Heating and Air Conditioning Systems, Sheet Metal and Air Conditioning Contractors National Association, Inc., 1985.

TIMA-1 Fibrous Glass Duct Construction Standards: Low Velocity Systems, 2 Inches WG Maximum Static Pressure, First Edition, Thermal Insulation Manufacturers Association, 1989.

UL-1 UL181, Standard for Factory-Made Air Ducts and Connectors, 1990, Underwriters Laboratories, Inc.

UL-2 UL181A, Closure Systems For Use With Air Ducts And Connectors, 1989, Appendix A of Standard UL181, Underwriters Laboratories, Inc.